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Implicit PPV schemes and Newton Method to solve
CFD Problems of viscous external aerodynamics

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Keywords: Newton method, high resolution PPV-schemes

ABSTRACT

The efficiency of the Newton method [1] and high resolution PPV schemes [2] to solve steady Navier-Stokes equations is assessed. Linear systems on each Newton iteration step are solved using either iterative (GMRES [3] preconditioned by the incomplete LU decomposition by positions), or direct (nested dissection method [1]) large sparse matrix inversion procedure.

Linear system coefficients are computed using numerical differentiation. As test problems, two-D viscous transonic flows about circular cylinder and NACA0012 airfoil are considered.

An influence of a PPV scheme option, the linear system solution accuracy, Newton method initial guess choice and associated CPU time savings are analyzed. The Newton method convergence rate at different Mach and Reynolds numbers generally proves to be linear.

A significantly influenced by local supersonic zones and shocks, the allowed accuracy of the linear system solution for the Newton method convergence is found to vary depending on the concrete problem. Used with care, iterative solvers are several times (5-10) faster and economic, than direct ones, which in their turn, do not show problem parameter-dependent performance.

From the three possible variants of an initial guess to compute with a high resolution PPV scheme, namely free-stream flow, first-order solution or the second order solution at different Mach and/or Reynolds numbers, the most successful is the second variant. This is because otherwise the shock location is far from being exact, and at each Newton iteration step present in a PPV scheme a smooth nonlinear limiter function makes the quadratic convergence rate of the Newton method linear.

It is shown, that using simplified PPV schemes one can in certain cases save total computer time needed to get the converged solution, up to 30%, compared to the classical 3-wave PPV model (a.k.a. Roe) scheme [2].

At the moment the algorithm described is built into a TsAGI CFD library A+M for large-scale computations.

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A METHOD TO CONSTRUCT GODUNOV-TYPE SCHEMES

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Keywords: Godunov-type schemes, numerical viscosity matrix

ABSTRACT

Godunov-type schemes [1-5] were a considerable success of last two decades CFD. These schemes are stable, monotone and serve as a building block for modern high-resolution schemes (see e.g. [6]), yet methods of their construction lack unification and sometimes simplicity. We present an approach, allowing to simplify greatly coding and understanding of how to construct Godunov-type schemes. The method is aimed at a proper construction of numerical viscosity matrices, associated with Godunov-type schemes, and allows their clear geometrical interpretation. One can easily modify numerical viscosity matrices when needed: the result is a simple, economic and reliable algorithm.

The ground idea of the method PPV (Polynomially Presented Viscosity) is to express a numerical viscosity matrix of a scheme as a quadratic or linear polynomial of a gasdynamics Jacobian matrix [5].

The degree of unification offered by the method is such that among examples of its realization are schemes due to Roe [2], Steger-Warming [3], van Leer [4] and some other algorithms, not widely used to-date.

At the moment the PPV-schemes are exploited in a CAHI CFD library A+M [7] for large-scale computations.

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